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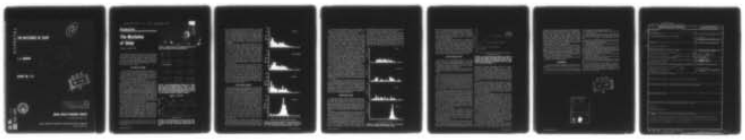

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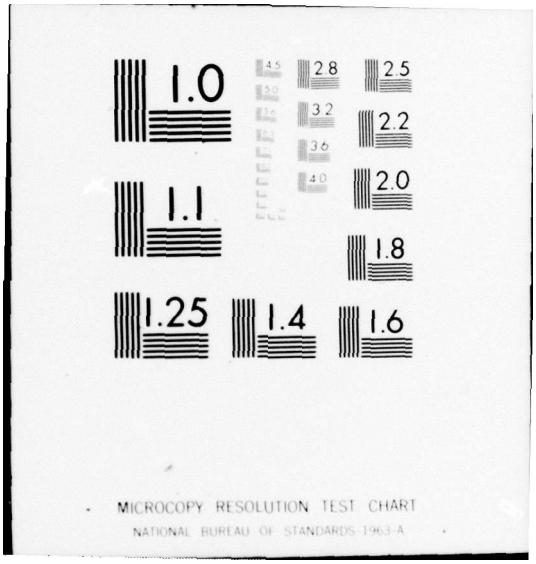
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THE MYSTERIES OF SLEEP

L. C. JOHNSON

REPORT NO. 77-4

NAVAL HEALTH RESEARCH CENTER
SAN DIEGO, CALIFORNIA 92152

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Features

The Mysteries of Sleep

Laverne C. Johnson, Ph.D.

FIGURE 1. Subject wired for an all-night sleep study at the Naval Health Research Center sleep laboratory.

How much sleep do we need? Is deep sleep better than catnaps or dozing? How long can we go without sleep? Must we get our sleep in a single chunk or can we take it in "three square naps" a day? These questions have been keeping staff members at the Psychophysiology Division, Naval Health Research Center, San Diego, awake at night.

NATURE OF SLEEP

In the past 20 years, there has been a dramatic increase in research on the one-third of our lives most of us spend sleeping. One consistent finding: sleep is not a quiet period, nor is it a period of unconsciousness. Sleep has its own unique pattern of physiological, biochemical, hormonal and mental activity.

Consider the electrical activity of the brain. Electroencephalographic (EEG) studies show that sleepers' brain patterns vary from the low-amplitude brain-wave patterns of sleep onset to the high-amplitude delta (1 Hertz) waves of deep or "slow-wave" sleep. Rapid eye movements (REMs) during sleep are associated with a low-amplitude EEG pattern very much like the pattern seen during sleep onset (*1,2*). During this REM stage of sleep, the subject is most likely to dream, although dreamlike mental activity occurs in all sleep stages. (It was the belief that they had identified dreaming, the royal road to the unconscious, that sparked much of the enthusiasm of early sleep researchers.)

When subjects are wired for sleep recordings (Figure 1), EEG patterns typical of the five sleep stages are seen (Figure 2). These clearly defined EEG patterns dispelled the belief that sleep was a homogeneous state which varied only in depth. Instead, during sleep a person goes through a regular pattern, as shown in the sleep profiles of two subjects (Figure 3). Each subject begins with stage 1, goes on to stages 2, 3 and 4, then back to stage 2. From 90 to 100 minutes after sleep on-

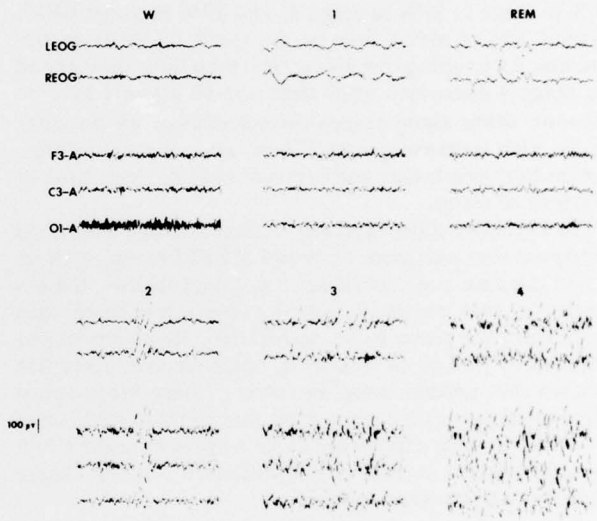

FIGURE 2. Electroencephalograph readings show a subject awake (W) and in five stages of sleep: 1, REM, 2, 3, and 4. Each reading covers about 20 seconds. LEOG and REOG mean left and right electroculogram referenced to mastoid. F3-A, C3-A and 01-A indicate (respectively) left frontal, central, and occipital electrode referenced to mastoid.

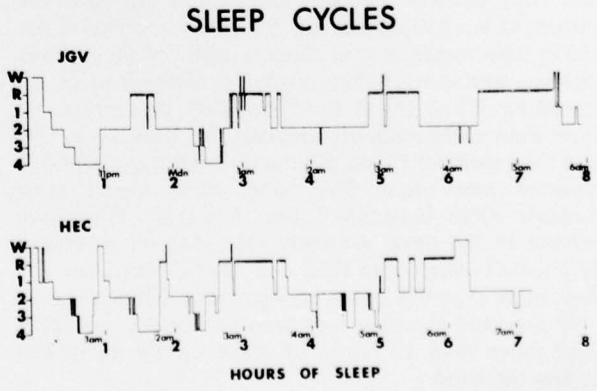

FIGURE 3. All-night sleep profiles of two young adult males. The subject of the upper profile went to sleep at 2200, while the subject of the lower reading began sleeping near midnight.

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set, the subject usually goes from stage 2 to stage REM. With slight ups and downs, the subject then returns to stage 2, possibly goes on to stage 3, back to 2, then again to REM with a return to stage 2. (Ordinarily, a normal, healthy subject enters a REM period only from stage 2.) Periods of slow-wave sleep (stages 3 and 4) usually disappear as sleep continues, until during the last part of a night's sleep stage 2 alternates with REM.

Whether people go to bed at 2200 or 0200, they follow the same cycle. Night workers also follow this cycle during daytime sleep. The average young adult spends 6% of his or her sleep time in stage 1, 50% in stage 2, 7% in stage 3, 16% in stage 4, and 20% in stage REM. About 1% of sleep time is occupied by body movements. As people grow older, the sleep time they spend in stage 4 decreases until after age 60 stage 4 may be absent; other sleep stages do not change as dramatically with increasing age. There are no major differences between males and females in total sleep time or pattern of sleep.

In the early days of sleep research, some scientists believed that adequate amounts of REM sleep, with its vivid dreams, are crucial for emotional health. Others believed that stages 3 and 4 (slow-wave sleep) are necessary for sleep to be restorative. Research in our laboratory (*3,4,5*) as well as in other sleep centers has shown that neither belief is correct: there are no firm data to show that the amount of time spent in REM or in slow-wave sleep affects behavior or performance when an individual is awake. The significance of sleep stages remains an unsolved mystery.

HOW MUCH SLEEP?

The total *amount* of sleep appears to be the most important factor affecting awake behavior and performance. When we asked 750 students at the Naval School of Health Sciences, San Diego, how long they sleep, the most obvious difference was the wide variations in the amount of sleep reported. A preliminary analysis of our survey also suggests that sleep lengths of these Navy students are shorter than students' sleep lengths reported by Webb (*6*) at the University of Florida. Of more than 4,000 students entering the University, 7% said they slept less than 6½ hours each night and 3% reported more than 9½ hours each night; most students slept between 7 and 8 hours. Thirty-five percent of the naval students said that on workdays they usually slept less than 6½ hours; less than 1% slept more than 9½ hours on workdays. On weekends, 12% reported sleeping less than 6½ hours, but 22% slept more than 10 hours to make up for sleep lost during the week.

The easiest way for people to tell whether they are getting enough sleep is to note their sleep habits and their condition after waking. If someone needs an alarm clock to wake up, tends to doze off shortly after getting

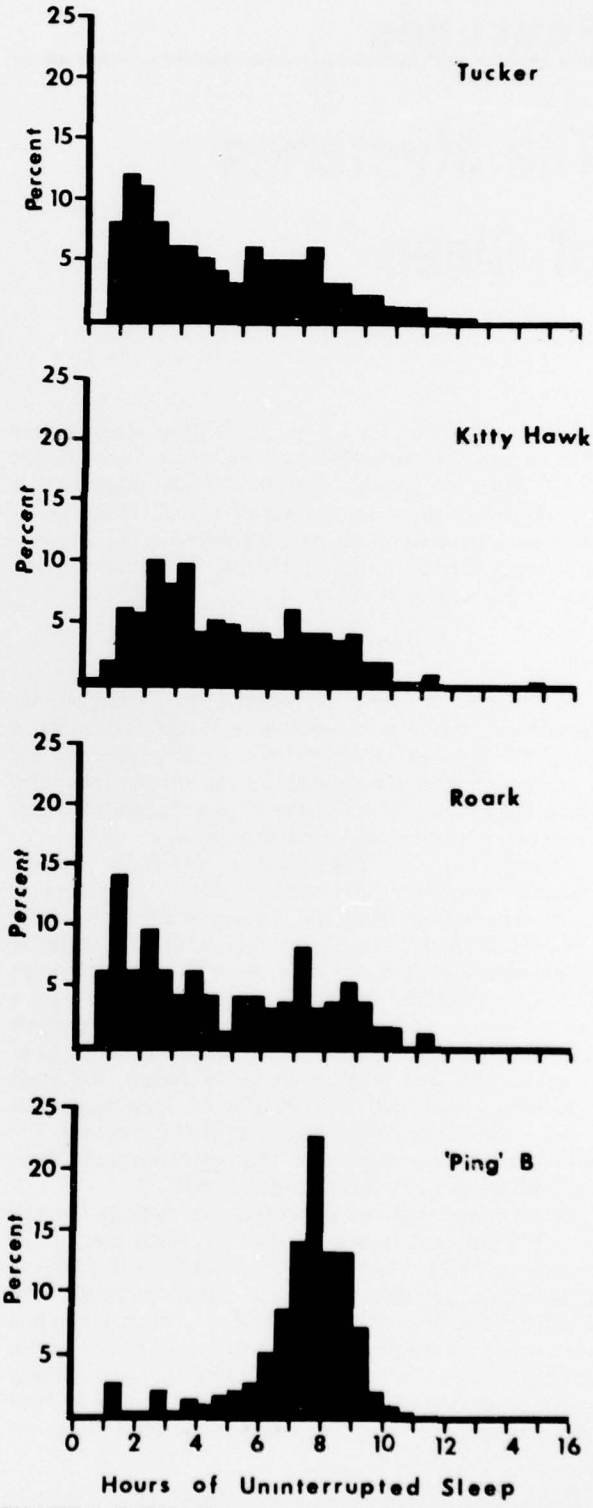

FIGURE 4. Profiles show periods of uninterrupted sleep for crewmembers aboard the USS Tucker, USS Roark and USS Kitty Hawk, and among shore-based personnel ('Ping' B).

up, or falls asleep during lectures, conversations, or reading—and if there are no contributing health problems—he or she probably needs more sleep.

While regular sleep habits do not necessarily ensure an adequate amount of sleep, irregular sleep habits almost always lead to a sleep debt, and may cause disorders in chemical and physiological rhythms which are normally on a 24-hour schedule. In the Navy it is difficult to maintain a regular sleeping schedule during shipboard watch schedules. About three years ago, Paul Naitoh, Ph.D., a psychologist on our staff, compared sleep schedules aboard the carrier USS *Kitty Hawk* and the destroyers USS *Tucker* and USS *Roark* with the sleep of men in land-based barracks (called 'Ping' B in the study). Under 'Ping' B conditions, 75% of the men's sleep was uninterrupted for 6 to 9½ hours, and the group's sleep pattern was symmetrical (Figure 4). But shipboard sleep differed considerably: only about 30% to 35% of the crew obtained 6 to 9 hours of uninterrupted sleep, while approximately 50% of the crew got less than 4 hours of uninterrupted sleep.

Even more striking was the disruption of the sleep/wake cycle in shipboard sleep (Figure 5). Most of us prefer a schedule of 8 hours of sleep followed by 16 hours awake. 'Ping' B conditions reflect this preference, with most subjects reporting 16 to 18 hours between sleep periods. Again, shipboard sleep was dramatically different: the sleep/wake cycle was clearly fragmented, with the time between sleep ranging from 1 to 22 hours.

Do these disruptions in sleep patterns affect the crew's performance and health? In a study of carrier flight operations during the Vietnam War, Brictson and associates (*7*) found that the more fragmented the sleep/wake schedule, the worse the carrier landing performance. However, the total amount of sleep obtained over each 24-hour period was not significantly associated with landing performance.

REDUCING SLEEP

People often tell me that they could get more out of life if they didn't sleep so much, and ask, "Can I reduce my sleep?" The answer is *yes*—but it's not easy, and abrupt reductions in sleep time usually do not last. When the immediate need to reduce sleep passes, most people return to their former sleep schedule. However, when sleep is reduced gradually the change tends to persist.

When the Naval Health Research Center collaborated with the Psychiatry Department of the University of California, Irvine, on a sleep reduction study, we observed gradual sleep reduction in three couples who customarily slept 8 hours, and in one couple who slept 6½ hours a night. Each subject was asked to reduce his or her sleep by 30 minutes every three or four weeks, with the final amount of sleep reduction left for the subjects to determine based on their feelings and awake performance. Sleep was monitored by logs each subject kept and by recordings of EEG activity.

Among the 8-hour sleepers, two subjects reduced their sleep to 4½ hours, two to 5 hours, and two to 5½ hours. The two 6½-hour subjects stopped reducing their sleep time at 5 hours. All subjects said that fatigue and difficulty in getting up were their main reasons for stopping, even when awake performance was not seriously impaired. At the end of a follow-up year, all subjects were sleeping at least one hour less than

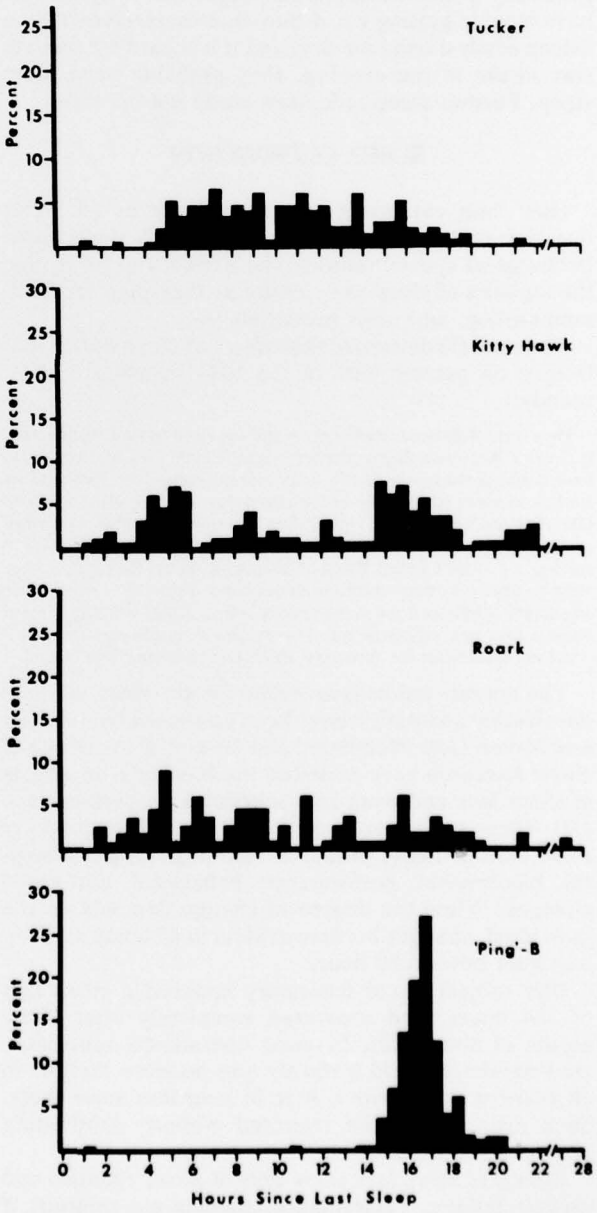

FIGURE 5. Profiles of shipboard and 'Ping' B sleep/wake cycles reflect fragmentation of shipboard sleep.

before the study and two subjects were sleeping two hours less. Mood and feelings of fatigue had returned to pre-study levels, even though sleep was reduced. The 6½-hour couple returned to their customary routine during follow-up, indicating that 6½ hours was their minimal sleep time.

These results suggest that some of us can function well on less sleep. But would it be worth the effort? For a lasting change, our sleep/wake cycle requires a gradual shift that allows our biological rhythms to adjust gradually. As noted earlier, if people feel fatigued and have trouble getting up, if they find themselves falling asleep easily during the day, and if it is hard for them to stay awake in the evening, they probably need more sleep. Further sleep reduction would not be wise.

SLEEP DEPRIVATION

How long can we go with no sleep at all? This question faces many commanding officers and people in charge of special military operations who must plan the logistics of sleep as carefully as they plan for food, ammunition, and other essentials (*8*).

Marshall (*9*) described the effects of sleep deficit and fatigue on paratroopers in the 1944 invasion of Normandy:

> They were dull-eyed, bodily worn and too tired to think connectedly. Even a 30-minute flop on the turf with the stars for a blanket would have doubled the power of this body and quickened the minds of its leaders to ideas which they had blanked out. But no one thought to take that precaution. The United States Army is indifferent toward common-sense rules by which the energy of men may be conserved in combat. . . . Said Captain Patch of his people on the far right, "They were so beat that they could not understand words even if an order was clearly expressed. I was too tired to talk straight. Nothing I heard made a firm impression on me. I spoke jerkily in phrases because I could not remember the thoughts which had preceded what I said."

The operational consequences for air crews of sleep deprivation and deficit have been discussed by Johnson and Naitoh (*10*); Woodward and Nelson of the Office of Naval Research have reviewed the literature on effects of sleep loss and work-rest schedules on performance (*11*). These two reports conclude that total sleep loss of more than 60 hours produces neurological, physiological, biochemical, performance, behavioral, and mood changes. While the degree of change depends on the individual, changes become evident in all areas as sleep loss goes beyond 60 hours.

One subject in our laboratory endured a sleep loss of 264 hours, and recovered completely after three nights of sleep (*12*). In most operational schedules, crewmembers would probably lose no more than 40 to 48 hours of sleep, with a 30 to 36 hour loss more likely. Such amounts can be tolerated without debilitating physiological changes.

Effects of sleep loss show first in mood changes and greater fatigue. Performance changes are minimal if tasks are brief, self-paced and highly motivating, and if the worker is given some idea of the adequacy of his

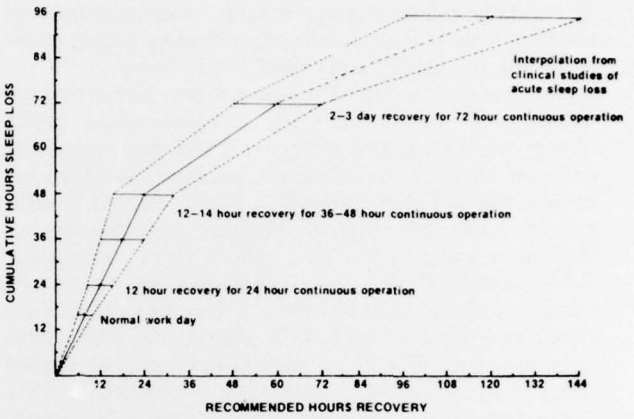

FIGURE 6. As hours of sleep loss increase, so do hours of recovery sleep needed. The dotted lines indicate that the variability of this ratio (hours of sleep/hours of recovery sleep required) also increases as the subject loses more sleep. (From Woodward and Nelson, 11)

performance. People performing tasks that require sustained vigilance and attention, use of newly acquired skills, retention of new information, and a long time to complete are more likely to show sleep-loss effects. Most of the decrement in performance will occur during brief periods of "microsleep" which occur as the person is working. These effects are more likely to occur in the early morning, when body temperature is low.

To minimize such effects, work should be reduced during hours when sleep would normally occur, regardless of the actual time of day. For example, travel in jets often results in duty schedules falling at times when one would normally be asleep. This "jet lag" effect and its relation to sleep loss must be taken into account in setting duty schedules.

After 36 hours of continuous duty, how much recovery sleep is required? Based on current research and operational data, Woodward and Nelson (*11*) have provided a useful guide for estimating recovery sleep times (Figure 6). For example if a man's duty results in 36 cumulative hours of sleep loss, he could find the recommended hours of recovery by noting the point on the guide where 36 hours of sleep loss (see vertical axis) intersects the solid line. Then, he would draw a vertical line from that point to the horizontal "hours of recovery" scale. For 36 hours of sleep loss, 18 hours of recovery are recommended. For 72 hours of sleep loss, 60 recovery hours are recommended. After 36 or 72 hours of sleep loss, it is highly unlikely that anyone would spend all of the recovery time in continuous sleep. The young man who was awake for 264 hours in our laboratory slept only 15 hours before awakening.

The Naval Health Research Center's psychophysiology laboratory is conducting a study of poor sleepers. We also plan to continue studying variations in sleep

schedules, with particular attention to determining the optimal wake-sleep schedule for effective performance after varying periods of sleep loss. Our results so far suggest that required sleep lengths and sleep schedules are flexible and can be adapted to a changed lifestyle. But the fact that none of our subjects' sleep time dropped below 4½ hours suggests there is a limit beyond which sleep cannot be reduced. The limit for fragmentation of sleep is still unknown.

Samuel Johnson, notes Webb (6), likened sleep to a gentle tyrant. To live on the best terms with a "gentle tyrant" one must learn the rules by which he governs. Being gentle, he permits us certain freedoms to manifest our individual variations and differences; being a tyrant, he will not permit us to live in total freedom, and abuses carry their ultimate consequences.

We hope our studies will shed some light on the rules acceptable to this "gentle tyrant."

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(U) This article reviews research done by the Psychophysiology Division concerned with sleep quality, sleep reduction, and total sleep loss. The description of the work is in a style appropriate for sailors and officers without prior knowledge of sleep research.

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